STXM-XANES ANALYSIS OF ORGANIC MATTER IN DARK CLASTS AND HALITE CRYSTALS IN ZAG AND MONAHANS METEORITES. Y. Kebukawa[1]*, M. E. Zolensky[2], M. Fries[2], A. Nakato[3], A. L. D. Kilcoyne[4], Y. Takeichi[5], H. Suga[6], C. Miyamoto[7], Z. Rahman[8], K. Kobayashi[1], K. Mase[5], and Y. Takahashi[7]. [1]Faculty of Engineering, Yokohama National University, 79-5 Tokiwadai, Hodogaya-ku, Yokohama 240-8501, Japan, [2]ARES, NASA Johnson Space Center, 2101 NASA Parkway, Houston, TX 77058, USA, [3]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency (JAXA), 3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210 Japan, [4]Advanced Light Source, Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, CA 94720, USA, [5]Institute of Materials Structure Science, High-Energy Accelerator Research Organization (KEK), 1-1 Oho, Tsukuba, Ibaraki 305-0801, [6]Department of Earth and Planetary Systems Science, Hiroshima University, Kagamiyama, Higashi-Hiroshima, Hiroshima 739-8526, [7]Department of Earth and Planetary Science, The University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, [8]Jacobs, NASA Johnson Space Center, Houston, TX 77058, USA. *Email: kebukawa@ynu.ac.jp

Introduction: Zag and Monahans meteorites (H5) contains xenolithic dark clasts and halite (NaCl) crystals [e.g., 1]. The proposed source of the H chondrites is asteroid 6 Hebe [2]. The modern orbits of 1 Ceres and 6 Hebe essentially cross, with aphelion/perihelion of Ceres and Hebe of 2.99/2.55 and 2.91/1.94 AU, respectively [3]. Therefore, Ceres might be the source of the clasts and halite in Zag and Monahans meteorites [4]. Recent results from NASA's Dawn mission shows that bright spots in Ceres's crater may be hydrated magnesium sulfate with some water ice [5], and an average global surface contains ammoniated phyllosilicates that is likely outer Solar System origin [6].

One dark clast and all halite crystals in Zag and Monahans meteorites contain carbon-rich particles. We report organic analyses of these carbon-rich particles using carbon, nitrogen, and oxygen X-ray absorption near edge structure (C-, N-, and O-XANES), in order to constrain the origin of the clast and halite crystals

Samples and Methods: C-rich spots were selected in the Zag dark clast using SEM and approximately 100 nm-thick sections were prepared using a focused ion beam (FIB) at JSC. C-rich residues were obtained after dissolving halite crystals in the Monahans meteorite. The residues were embedded in sulfur and ultramicrotomed with a diamond knife. The sections were analyzed using the scanning transmission X-ray microscope (STXM) on beamline 5.3.2.2 at the Advanced Light Source, Lawrence Berkeley National Laboratory, or BL-13A at the Photon Factory, KEK.

Results: *Zag clast C-rich spots.* Fig. 1 shows STXM carbon map of FIB sections of the Zag clast that contain micrometer-sized C-rich spots. C-XANES spectra were obtained from the C-rich spots and surrounding matrix of the clast (Figs. 2, 3). C-rich spots from FIB#2 show a peak at 284.8 eV that is assigned to aromatic/olefinic C=C. C-rich spots from FIB#1 show peaks at 286.3 eV that is assigned to aryl/vinyl-keto C=O, and 288.5 eV that is assigned to carboxyl/ester COOR, in addition to C=C peak. C-XANES of the matrix area shows 290.3 eV assigned to carbonates with some aromatic/olefinic C=C.

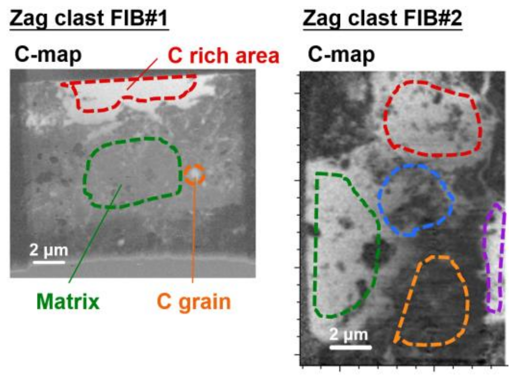

Fig. 1: STXM carbon map of the Zag clast FIB sections. C-rich areas are shown in light gray. C-XANES of selected areas are shown in Fig. 2,3.

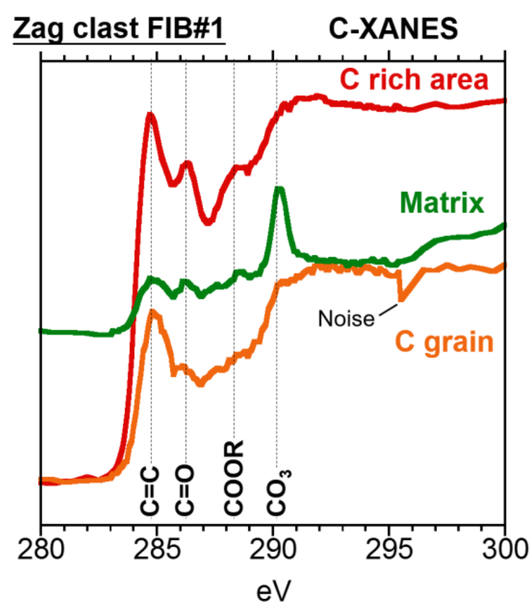

Fig. 2: C-XANES spectra of the Zag clast FIB#1. Corresponding C-map is shown in the left panel of Fig. 1.

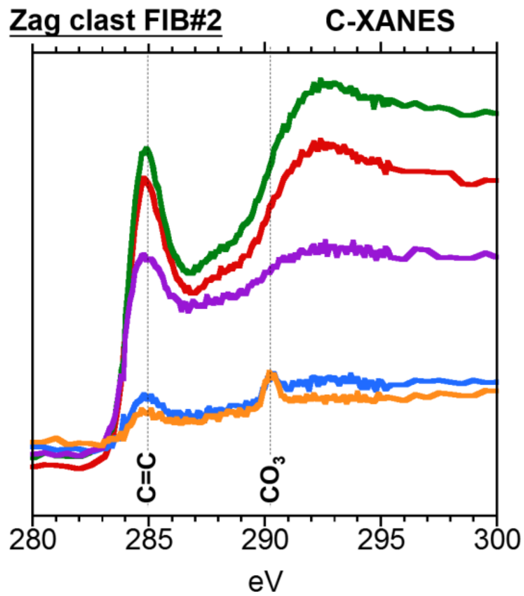

Fig. 3: C-XANES spectra of the Zag clast FIB#2. Corresponding C-map is shown in the right panel of Fig. 1.

The peak assignments are based on [7] and shown in Table 1. No specific N-XANES features are observed in the Zag clast (data not shown).

Table 1: C-XANES peak assignments based on [7].

Energy (eV)	Functional group
284.8–285.0	C=C Aromatic/olefinic
286.3–286.7	C=O Vinyl-keto
287.5	C–C Aliphatic
288.5–288.7	COOR Carboxyl/ester
290.1–290.5	CO_3 Carbonate

Organic-rich residue from Monahans halite. We obtained C-XANES spectra from several ultramicrotomed thin sections of the organic-rich residue from Monahans halite. Typical C-XANES spectra are shown in Fig. 4. The peak assignments are shown in Table 1. There were two types of spectra obtained from the Monahans residue. Type 1 shows large C=C with some aliphatic and COOR peaks. Type 2 shows a large COOR peak with C=C peak. Some analyzed areas also show carbonates.

Discussion: A large (>5 µm) carbon chunk in Zag clast FIB#1 shows similar C-XANES features with insoluble organic matter (IOM) in CI-CM-CR chondrites [8, 9]. A C-rich grain (<1µm) in FIB#1 and C-rich areas in FIB#2 have no organic features except C=C at ~285 eV. This characteristic is similar to some nanoglobules in carbonaceous chondrites [8] and coma particles from comet 81P/Wild 2 [10], but C-rich areas in FIB#2 are much larger than any nanoglobules.

C-XANES of Monahans residue type 2 shows some similarity to some of the comet 81P/Wild 2 particles [7], but type 1 does not resemble any extraterrestrial samples analyzed with C-XANES so far, to our knowledge.

The STXM-XANES analyses indicate that the Zag dark clast and the Monahans halite crystals contain comet-like organic matter as well as carbonaceous chondrite like organics. If these clasts and halite crystals originated from Ceres, it is consistent with the recent view of Ceres that it lies on a continuum in composition between asteroids and comets [5], also consistent with measured O and H isotopic composition of water from Zag and Monahans halite [11].

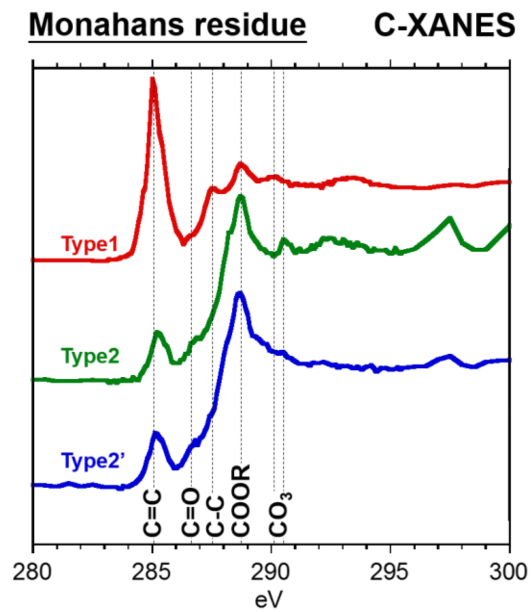

Fig. 4: C-XANES spectra of ultramicrotomed thin sections from the carbonaceous residue in the Monahans halite crystal.

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